1 EXECUTIVE SUMMARY

INTRODUCTION

This report responds to the requirements of Section 183(g) of the Clean Air Act Amendments (CAAA) of 1990, which requires that

> "The Administrator shall conduct a study of whether the methodology in use by the Environmental Protection Agency as of the date of enactment of the Clean Air Act Amendments of 1990 for establishing a design value for ozone provides a reasonable indicator of the ozone air quality of ozone nonattainment areas. The Administrator shall obtain input from States, local subdivisions thereof, and others. The study shall be completed and a report submitted to Congress not later than 3 years after the date of the enactment of the Clean Air Act Amendments of 1990. The results of the study shall be subject to peer and public review before submitting it to Congress." (PL 101-549, Sec. 183 (g))

Ground-level ozone, the primary constituent of smog, causes several adverse health and environmental effects, such as respiratory problems, crop loss and materials damage. EPA has established a national ambient air quality standard (NAAQS) for ground-level ozone. According to EPA regulations, an area is not meeting the ozone standard ("nonattainment") if the expected number of days per year with daily maximum l-hour concentrations greater 0.12 ppm is greater than 1. As of October 1994, there are 91 areas of the country that are designated as nonattainment areas for ozone.

The ozone design value is a surrogate measure of attainment status, a measure of progress, and an indicator of how much concentrations must be reduced to meet the standard. The EPA design value method yields an estimate for the ozone design value that is consistent with the current ozone NAAQS. The current EPA design value method is simply to select the fourth highest daily maximum l-hour concentration as the design value during the 3-year compliance period (Laxton, 1990). The fourth highest value is the design value, since if the fourth highest day is reduced to the level of the standard, then there will be one day per year above the level of the standard assuming three years of data.

With passage of the Clean Air Act Amendments (CAAA) of 1990, added emphasis was placed on ozone design values. In addition to designating areas as nonattainment for ozone, the CAAA introduced a classification process to further categorize nonattainment areas according to the extent of their ozone problem. As shown in Table 1-1, this area classification was based upon the ozone design value. The CAAA stated that the design value "shall be calculated according to the interpretation methodology issued by the Administrator most recently before the date of the enactment." Before the 1990 CAAA, designation of nonattainment areas simply involved a yes/no determination as to whether the area met the standard. The additional classification step introduced by the 1990 CAAA placed greater emphasis on ozone concentration observations and on the methodology used to determine the design value.

TABLE 1-1. Ozone classifications specified in the 1990 Clean Air Act Amendments.

Area Class	Design Value*	Attainment Date**
Marginal	0.121 up to 0.138	3 years
Moderate	0.138 up to 0.160	6 years
Serious	0.160 up to 0.180	9 years
Severe	0.180 up to 0.280	1.5 years
Extreme	0.280 and above	20 years

*The design value is measured in parts per million (ppm).
**The primary standard attainment date is measured from the date of the enactment of the Clean Air Act Amendments of 1990.

Another reference to the use of design values is contained in Section 181(b)(2) of the Act, which states that EPA "shall determine, based on the area's design value (as of the attainment date), whether the area attained the standard by that date." EPA's preliminary interpretation of this Section is that the "average number of exceedances per year shall be used to determine whether the area has attained" which is the attainment test for the ozone' National Ambient Air Quality Standard (NAAQS) (Federal Register, 1992).

National Ambient Air Quality Standard for Ozone

In 1979, EPA promulgated the ozone NAAQS at a level of 0. 12 ppm that is attained "when the expected number of days per calendar year with maximum hourly average concentrations above 0.12 part per million (235 $\mu g/m^3$) is equal to or less than 1 as determined by Appendix H" (4OCFR 50.9). The attainment test specified in Appendix H states that the "expected number" of days with concentrations above 0.12 ppm ("exceedance" days) is to be estimated by calculating the average number of exceedances during the most, recent three years. Additional information is contained in Appendix H and the EPA Ozone Guideline on procedures for dealing with missing data (EPA, 1979). The Guideline makes it clear that the expected exceedance criterion is to be applied independently to each monitoring site. For areas with multiple monitoring sites, all sites within the nonattainment area must meet the standard for the area to be designated in attainment of the ozone NAAQS.

Ozone Design Values

As noted above, compliance with the ozone NAAQS is judged on the basis of expected exceedances, and becomes a "yes/no" decision. However, once it is established that an area exceeds the standard, the next logical question to ask is, "By how much?" The air quality design value is intended to provide a measure of how far concentrations must be reduced to achieve attainment or, equivalently, how far out of attainment the area represented by a monitoring site is. In this respect, the design value can be viewed as an air quality indicator for a given location.

Given the expected exceedance form of the ozone NAAQS, the design value for this standard is defined in the EPA guideline document as "the concentration with expected number of exceedances equal to one" (EPA, 1979). Note that in this context the ozone guidelines are referring to the unknown "true" number of expected exceedances per year rather than the estimate of expected exceedances determined using the Appendix H calculations. In statistical terms, this is the value which is exceeded once per year on average. If the daily maximum ozone concentrations are assumed to be independent and have the same distributions every day throughout the year, then the design value is the characteristic largest value (CLV) of that distribution. The Ozone Guideline described several different options for estimating design values, including a table look-up approach, graphical procedures, and fitting statistical distribution. The current EPA design value method is simply to select the fourth highest daily maximum l-hour concentration as the design value during the 3-year compliance period (Laxton, 1990). The fourth highest value is the design value, since if tbe fourth highest day is reduced to the level of the standard, then there will be one day per year above the level of the standard assuming three years of data.

Strictly speaking, the design value is an unknown quantity depending on the underlying distribution of ozone concentrations, and the EPA design value and alternatives are estimators of the (true) design value. To retain the readability of this document the term "design value" may refer to either the unknown population value or an estimator, depending on the context in which it is used. Where appropriate, the term "true design value" is used for clarification. The "EPA design value" always refers to the table look-up value.

Regulatorv Historv of Design Values

Beginning in the 1970's, air quality design values were used as the primary input to simple air quality models, such as the "rollback model" and the Empirical Kinetic Modeling Approach (EKMA) (deNevers and Morris, 1975; Meyer et al., 1977). These models were used to estimate emission reductions needed to attain the NAAQS and to evaluate alternative control strategy options (deNevers and Morris, 1975; Meyer et al., 1977; Wilson and Scruggs, 1980). This use of ozone design values diminished following the development of more complex photochemical modeling approaches (EPA, 1981; EPA, 1991b). In some applications, design values used in estimating emissions reductions have been adjusted to account for factors such as the level of transported ozone, or air quality reductions expected from future control measures (Meyer, Gipson, and Freas, 1977; Wilson and Scruggs, 1980). Such adjusted design values have come to be known as "control strategy values" to differentiate them from "air quality" design values, which are estimated directly from the ambient monitoring data (Rhoads and Tyler, 1987).

To support the passage of the Clean Air Act Amendments, EPA began issuing annual lists of areas failing to meet ozone and carbon monoxide NAAQS which contained their corresponding air quality design values (EPA, 1987, 1988, 1989, 1990, 1991a, 1992b). It is clear from the language of the CAAA of 1990, and the legislative history of the Act, that the initial area classifications were to be based on the air quality design value, which is the primary focus of this study (EPA, 1993). However, issues such as adjusting ozone design value for transport, emissions trends, and meteorological variability are addressed in this study within the context of "control strategy values."

EPA Design Value Methodology

The design value associated with the ozone NAAQS is an abstract quantity that can only be estimated from available data. The Ozone Guideline suggests several methods for estimating the design value, including a simplified table look-up procedure, approaches using statistical distributions, and techniques based on conditional probabilities. No single approach was required by the Guideline.

The table look-up procedure, summarized below in Table 1-2, has been designated as the EPA design value estimation method (Laxton, 1990). Basically, the tabular method identifies the lowest observed concentration that was not exceeded more than an average of once per year during the measurement period. This methodology is essentially unchanged from the State Implementation Plan (SIP) guidance issued in 1981, and is the method that was used for all of the annual design value lists issued by EPA and the initial ozone area classifications (EPA, 1981, 1987, 1988, 1989, 1990, 1991a,b, 1992, 1993; 40CFR58). Using the tabular method focuses attention on a concentration that was actually observed. as compared to a statistical fitting technique that could yield a design value that does not correspond to a concentration observed on a particular day. The tabular approach has several additional advantages not always shared by more complex statistical procedures. First, estimates can be made quickly, and directly, from existing summaries of air quality data. Second, the design value estimates are reproducible and verifiable with actual monitoring data. Third, it provides a uniform approach for all areas. It is also worth noting that current monitoring regulations do not require the reporting of hourly ozone data for all sites across the nation (Federal Register, 1991). Thus, statistical approaches which require fitting distributions to all the data, or even the upper 10 percent of the distribution, are not applicable for sites that only report summary statistics and not the individual hourly concentrations, or daily maximum l-hour values.

TABLE 1-2. Ozone design value rank based on number of years of data.

Number of Valid Years (at least 75% of days during designated ozone season)	Ozone Design Value Rank (daily maximum 1-hr concentration)
less than one valid year	highest daily maximum
1 year of data	2nd highest daily maximum
2 years of data	3rd highest daily maximum
3 years of data	4th highest daily maximum

THE OZONE DESIGN VALUE STUDY

Section 183(g) of the Act directs EPA to conduct a study of the methodology currently in use for calculating design values to determine if the calculated design value "provides a reasonable indicator of the ozone air quality of ozone nonattainment areas." Thus, the focus of the study is on the design value methodology as initially developed in the Ozone Guideline and later defined in current EPA guidance (40CFR50.9; EPA, 1979; Laxton, 1990). Issues concerning the form of the current ozone NAAQS are more properly treated within the existing mechanism for NAAQS review. EPA is in the midst of reviewing the ozone NAAQS. The Agency intends to propose any change to the standard by Spring 1995 and, after taking public comment, will promulgate the final decision in Spring 1997.

The "reasonable indicator" evaluation is dependent on the intended application of the design value. It is quite possible that a design value estimation procedure that provides a reasonable indicator for tbe purpose of determining the nonattainment classification of a small geographic area surrounding a monitoring site may not be suitable for the purpose of estimating the required degree of emission reduction needed to achieve attainment or for the purpose of estimating health risks to nearby populations. Therefore, it is necessary to indicate the intended application of a design value estimation procedure before judging whether it yields a reasonable air quality indicator. This issue can be examined in both a temporal and a spatial framework.

Spatial Representativeness

Design values are estimated individually for each momtor in an area, and the maximum value is used to determine the nonattainment classification of the entire area. Ozone concentrations can also be locally depressed immediately downwind of a source of nitrogen oxides (NO_x) due to scavenging by nitric oxide (NO). Key concerns are (1) whether the monitoring network is sufficiently dense and monitors are appropriately located to represent air quality over the area in question and (2) how spatially uniform are design value estimates' across metropolitan areas. The study examined the spatial distributions of ozone ambient concentrations from existing monitoring networks within urban areas. Figure l-l shows the variability in 1987-89 ozone design values calculated for all monitoring sites in the northcentral states of Indiana, Illinois, Michigan, and Wisconsin. As illustrated, design values can vary from levels near the standard to levels near 0.20 ppm at sites across these states. The study also described regional-scale ozone episodes and examined large-scale features using spatial concentration distributions calculated by photochemical dispersion models.

Temporal Representativeness

A major concern with respect to the temporal representativeness of design values is the number of years of data used to calculate the design value. Current EPA guidance calls for the use of three years of data, if available (40CFR50.9). The use of three years of data is a compromise between the need to include as much data as possible to arrive at an accurate estimate and the need to recognize nonstationarities in the data record resulting from precursor emission trends. Setting the time period for judging compliance also sets an upper limit on the number of exceedances that a site can experience in any one year and the area still remain in attainment of the NAAQS.

Wide year-to-year variations in weather conditions can result in significant differences in estimated design values from one three-year period to the next, even in the absence of emission changes, as shown in recent design value lists that include 1988 ozone data. Meteorological conditions in 1988 were highly conducive to ozone formation, especially in the eastern half of the nation. Summer 1988 was the third hottest summer on record (Heim, 1988). Adding 1988 data to the three-year data window increased the number of areas not meeting the ozone standard to 98, an increase of 37 areas (EPA, 1989, 1990). More recent summers have been less conducive to ozone formation than the summer of 1988. In the East, the period from January through July 1989 was among the wettest on record (Heim, 1988). In the Northeast, summer 1990 also had above-average precipitation (Heim, 1990). However, summer 1991, which was the eighth warmest summer on record, saw the return of ozone conducive conditions, especially in the Northeast (Heim, 1989). In addition to these meteorological differences, volatile organic compound emissions have been reduced since 1988 levels. The volatility of gasoline, measured as Reid Vapor Pressure (RVP), was reduced 11 percent between 1988 and 1989, and an additional 3 percent between 1989 and 199Q (Federal Register, 1989; MVMA, 1988a, 1988b, 1988c). As a result of both changing meteorological conditions and emissions reductions, the latest design value listing, based on 1991-93 data, showed that 55 of the initial 98 nonattainment areas now meeting the ozone NAAQS (EPA, 1994). This is the fourth update that does not include data from the 1988 peak ozone year. Seven of the original 98 nonattainment areas have already been redesignated to attainment. Thus, factors such as the sequence of meteorological conditions, and reductions in emissions can introduce temporal variability in design values.

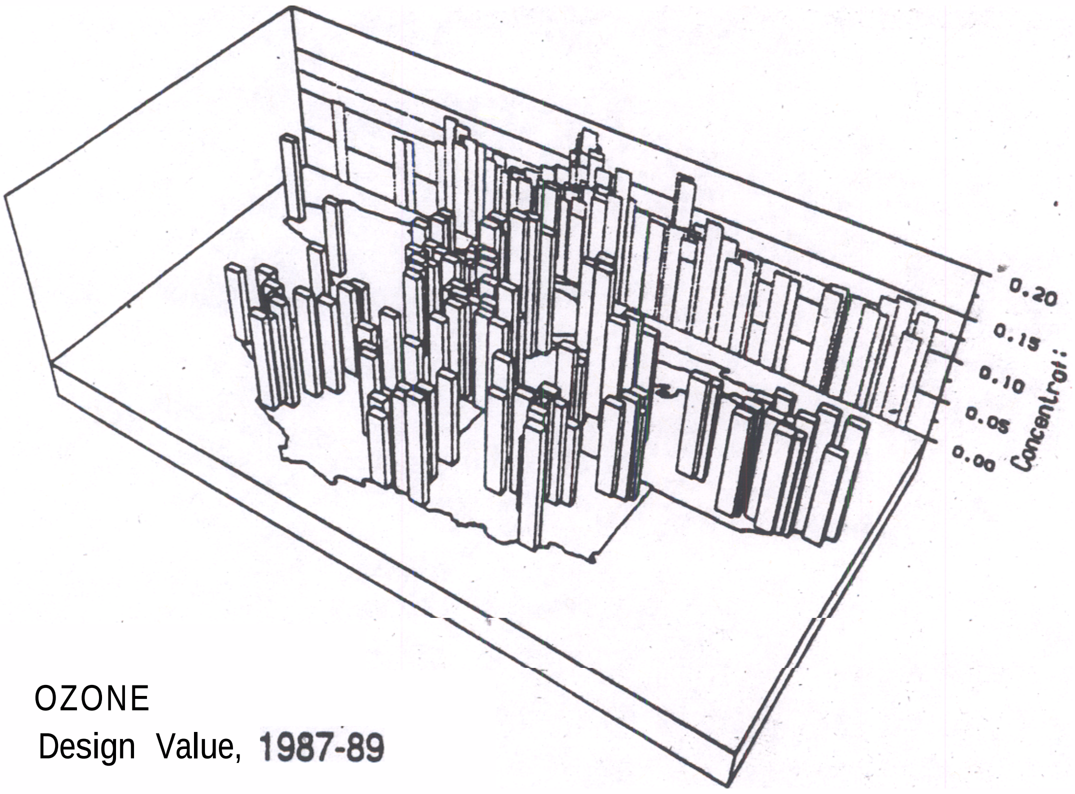

Figure l-l. Map depicting ozone design values at all sites in Indiana, Illinois, Michigan, and Wisconsin, 1987-89.

As another measure of temporal variability, Table 1-3 summarizes ozone area classifications that would result from increasing the number of years used in the EPA design value method. The table focuses on data windows ending in 1989, because most of the area classifications were based on data from that period (40CFR58). However, to maintain historical consistency, Consolidated Metropolitan Statistical Areas (CMSAs), Metropolitan Statistical Areas (MSAs), and counties are used to define the geographic area, and not the nonattainment area boundaries of the currently designated nonattainment areas. Table 1-3 shows that the largest differences in ozone area classifications are associated with design values based on a single year of data. There is close agreement between classifications based on 3 and 4 years of data, while the longer data windows (5 and 6 years) have fewer nonattainment areas (4 and 7 fewer, respectively) than the 3-year estimates. There is some downward movement in area classifications evident in the longer time periods. That is, severe areas have moved downward to serious, serious areas to moderate, and moderate areas to marginal.

TABLE 1-3. Impact on ozone area classifications of varying the number of years when estimating the ozone design value using the EPA tabular method.

Clean Air Act Ozone Classification	Number of Areas (CMSA/MSA/County)							
	Single Year Design Value			Multi-year Design Value				
	1987	1988	1989	1988-1989	1987-1989	1986-1989	1985-1989	1984-1989
Extreme	1	1	1	1	1	1	1	1
Severe	6	11	4	7	9	9	7	6
Serious	17	23	4	20	16	15	14	15
Moderate	22	45	12	36	33	33	33	29
Marginal	22	32	18	35	39	37	39	40
Total	68	112	39	99	98	95	94	91

ALTERNATIVE OZONE DESIGN VALUE ESTIMATION METHODS

The Ozone Guideline introduced several techniques that could be used to estimate design values including (1) a table look-up procedure (which evolved into the current EPA method), (2) the use of fitted statistical distributions, and (3) the use of a conditional probability approach.

There are two distinct approaches to fitting distributions to air quality data: (1) fitting parametric distributions to raw hourly or daily concentrations, and (2) fitting extreme value distributions to the highest concentrations. A review of the literature conducted for this study, including the reported goodness-of-fit results, suggests that a growing consensus appears to favor the use of the tail exponential distribution to fit the annual maximum hourly ozone concentrations. The use of the lognormal distribution to fit the hourly and, possibly, daily maximum hourly, ozone concentrations was another popular method (Mage, 1984; Curran and Frank, 1975). The selection of a "best" statistical distribution for calculation of ozone design values may not be possible because such a distribution probably varies according to the location studied and the time period of interest. An approach developed by Breiman for EPA fits an exponential distribution to the upper 5 to 10 percent of the concentration distributions for each year (Breiman et al., 1978). Ozone' design values are estimated by combining the tail-exponential distributions for the three-year compliance period. Another approach is to combine data years and fit a parametric distribution to the upper tail of the three-year distribution. The tail exponential approach developed by Larsen and others at the California Air Resources Board (CARB, 1992b) was developed in response to the 1988 California Clean Air Act which allows highly irregular or infrequent violations of the state ambient air quality standards to be excluded from the attainment/nonattainment designation process (Larsen and Bradley, 1991; CARB, 1992a; Larsen, 1991). In June 1990, the California Air Resources Board (CARB) determined that exceedances expected to recur less frequently than once in seven years could be excluded. The tail exponential approach was proposed as a method of estimating the one-m-seven-year concentration. More recently, the CARB revised the exclusion frequency to be one in one year (CARB, 1992b).

Comparisons have been made of design values estimated using the EPA tabular approach and those estimated using exponential and Weibull distributions. These distributions were fitted to the upper 5 percent of the three-year distribution for 1987-89 at all ozone sites in the historical database using the Breiman tail-exponential procedure and by a procedure that estimated the parameters by maximum likelihood using a Newton-Raphson algorithm (Breiman et al., 1978; SAS; Freas, 1992a). The tabular method design value estimates tended to be lower than those obtained with the tail-exponential and other distribution fitting methods. Differences in the several parts per billion range were found among the various distribution fitting methods. Table l-4 presents the results for the Chicago, New York and Los Angeles metropolitan areas of using five different methods for estimating design values: (1) the EPA tabular approach, (2) simply using the appropriate percentile from the empirical distribution, (3) the Breiman tail-exponential fitted to the upper 5 percent of the data, (4) a 10 percent tail-exponential fit, and (5) the CARB tail-exponential approach developed by Larsen. The CARB approach was applied both with and without the empirical calibration factor used with the method. The calibration factor was determined by Larsen in a way that recognized the expected discrepancy between the tail-exponential method and the EPA tabular method, since the EPA method is expected to be biased low on theoretical grounds. According to the CARB (McGuire, 1994), the calibration factor estimate recommended by Larsen is based on ozone data from monitoring sites throughout

California and was selected to produce design value estimates at a "suitable midpoint" between the uncalibrated method and the EPA method.

Average and maximum values across all monitoring sites in these areas are listed in Table l-4. Details of the calculations, including the percentile definitions and confidence intervals, are provided in Section 6. The maximum values indicate the design value which would be assigned to the nonattainment area; assuming that design values from any monitors not included in this analysis are smaller. Except for design values based on the 10 percent tail exponential (and the 5 percent tail exponential in Los Angeles), the various methods produced estimated average design values that are within 0.01 ppm of each other. This is also true of the maximum design values in each area, except in Los Angeles where the differences were as large as 0.02 ppm. Of course, results at individual monitors may show wider variations. Design values obtained by fitting a tail exponential distribution to the top 10 percent of the data values are higher than even the third highest concentration in each area, both on average and for the maximum values. Lower design values were obtained from tail exponentials fitted to the top 5 percent of the ozone values although, on average, they are still higher than the third highest for the New York and Los Angeles areas. These results indicate that the portion of the distribution of daily maximum concentrations to which the tail exponential is fitted can have a significant impact on the estimated design value. This is the primary motivation for using Larsen's approach, which uses multiple tails fitted to various portions of me upper end of the distribution and weights the results toward those tails which best tit the available data.

If design values are to be estimated by fitting distributions, the tail-exponential distribution approach, using either the Breiman formulation or the CARB method, seems preferable on the basis of its simplicity, ease of fitting, robustness and goodness of fit. The goodness of tit for a large number of sites is likely due to the property that a wide variety of daily maximum ozone concentration distributions have an approximately exponential tail.

TABLE 1-4. Average and maximum estimated (ppm) design values for the period 1989-91 using each estimation method (4th High = fourth highest concentration, 3d High = third highest concentration, Pcntl = percentile method, 5%TlExp = 5 percent tail exponential, 10%TlExp = 10 percent tail exponential, Larsen = CARB method, LarNoCal = CARB method without calibration factor).

	4th High	3rd High	Pcntl	5%TlExp	5% TlExp 95%Confidence Interval Lower Bound	5% TlExp 95%Confidence Interval Upper Bound	10%TlExp	10% TlExp 95%Confidence Interval Lower Bound	10% TlExp 95%Confidence Interval Upper Bound	Larsen	LarNoCal
Chicago Area											
Average:	0.118	0.122	0.118	0.123	0.113	0.137	0.126	0.116	0.138	0.113	0.118
Max:	0.151	0.164	0.152	0.161	0.146	0.183	0.168	0.153	0.187	0.151	0.158
New York Area											
Average:	0.140	0.146	0.140	0.150	0.138	0.168	0.159	0.146	0.177	0.144	0.151
Max:	0.165	0.175	0.166	0.175	0.159	0.199	0.185	0.167"	0.209	0.166	0.175
Los Angeles Area											
Average:	0.21	0.22	0.22	0.25	0.22	0.30	0.26	0.23	0.30	0.21	0.22
Max:	0.28	0.30	0.30	0.32	0.29	0.38	0.34	0.31	0.39	.0.28	0.30

USE OF TIME-SERIES MODELS

In this study, time-series models were used as a tool for evaluating alternative design value estimation methodologies. The ambient ozone database was used to develop a time-series model of the behavior of daily maximum ozone concentrations. Given such a model, large numbers of random simulations of single seasons of daily maximum ozone values can be generated that allow the limiting CLV (the "true design value") and design values for any number of methods to be calculated over a large number of years. Thus, both the inherent biases and precision of alternative design value methods can be studied using a wide variety of averaging years. These data sets have no missing values and therefore are free from this source of error.

The time-senes model has been applied in five geographically diverse metropolitan areas: Atlanta, GA; Charlotte, NC; Chicago, IL-WI; Houston, TX; and New York, NY-NJ-CT. One hundred three-year sequences of ozone daily maximum concentrations were generated for key sites in each area. The results are similar to those observed with the ambient data comparisons. That is, the EPA tabular method gave lower'design value estimates, on average, than Breiman's tail-exponential method. However, tail exponential estimates at some individual sites can be lower than the EPA tabular values, depending on the shape of the concentration distribution.

PEER AND PUBLIC REVIEW

Section 183(g) of the CAAA of 1990 requires the EPA to "obtain input from States, local subdivisions thereof, and others." In conducting the Ozone Design Value Study, EPA has made every effort to have an open process and to ensure full public input and participation. These efforts focused on information exchange through participation in professional meetings and conferences, involvement of interested parties on the study working group, and holding a public meeting (Freas, 1992a, 1992b; Curran, 1992a, 1992b; 57FR34133). The study plan and the results of the multi-year analyses were presented in technical papers at the Air and Waste Management Association's Tropospheric Ozone Specialty Conferences. These papers were peer reviewed prior to publication in the Conference Proceedings.

A study review group has been established to provide input on technical issues and policy concerns. The group is composed of representatives from EPA program, research, policy and legal offices. State and local air pollution control agency officials also serve on the review group.

On September 10, 1992, EPA held a public meeting in Arlington, VA to obtain input on technical considerations and on implementation and policy issues to be addressed within the context of the Ozone Design Value Study. The meeting announcement was published in the Federal Register, and to ensure that all interested parties were aware of the public meeting, copies of the meeting announcement were sent to both individuals 'and organizations that had previously expressed interest in ozone-related issues (57FR34133). At the public meeting, presentations were made on behalf of the Motor Vehicle Manufacturers Association and Ford Motor Company. Written comments were received from ten respondents, representing State and local air pollution agencies, industry and private individual views.

On March 14, 1994, EPA published a *Federal Register* Notice announcing the availability of a draft report on the study for public review and comment. Prior to that announcement, copies of the draft report were mailed to all parties that previously expressed' an interest in the study. More than 250 copies of the report were mailed out in response to requests. As of the close of the public comment period on April 14, 1994, comments had been received from only two respondents. Requests were received from several parties to extend the comment period. On April 28, 1994, a second *Federal Notice* was published that extended the public comment period until May 31, 1994. Although many additional requests for copies of the draft report were answered during this period, only eight additional parties submitted comments by the close of the comment period. Technical peer review was conducted under the auspices of the National Institute of Statistical Sciences. The report responds to the public comments and was revised to address the technical corrections identified during peer review.

Comments received during the public meeting and on the draft report can be grouped into two major categories: (1) those relating directly to design value issues and (2) those that would require changes in legislation or a revision to the form of the ozone standard. Those in the first category include issues concerning (1) the statistical robusmess of the current design value methodology, (2) the precision and accuracy of ozone monitoring data, and (3) the use of other statistical techniques, such as fitting a tail-exponential model, for determining the design value. The second category includes issues associated with changing the form of the ozone standard to a more robust air quality indicator, or proposing to modify the attainment test to incorporate a statistical test, such as a "t-test" for judging compliance with the standard (Heuss, 1992; Chock, 1989, 1992; Heuss and Chock, 1992). Such changes are beyond the scope of this study and are more properly addressed during the next ozone NAAQS review.

OTHER CONSIDERATIONS

Many comments received raise issues related to the concept of a "control strategy" design value, not the air quality design value. Adjusting design values for factors such as transported ozone, meteorology, and emissions trends falls within the control strategy design value concept, not the air quality design value methodology used to classify ozone nonattaimnent areas under the CAAA of 1990.

Adjusting for Transported Ozone Levels

Transport of ozone and ozone precursors generated in one air basin can significantly influence ozone concentrations in neighboring air'basins located considerable distances downwind. Some comments received on the original nonattainment area classifications argued that EPA should have considered lowering the classification because of the impact of transport from upwind areas (Federal Register, 1991; EPA, 1992a). The amendments specifically acknowledge that transport across state boundaries plays a major role during high ozone events in the northeastern urban corridor between Washington, D.C. and Boston. Transport of ozone and precursors also plays a significant role in other parts of the country, including the Gulf Coast region and Lake Michigan. Although the amendments call for the establishment of a transport commission to study this issue, the Act does not provide for adjusting the air quality design values for transport. The one instance that transport may be considered during the initial classification process is if the design value is within 5 percent of the classification level.

As a result of the strong influence of transported precursors and ozone in some areas, design values at such locations may be heavily influenced by emission changes occurring many kilometers away in an upwind area. Adjusted design values differ from "current air quality design values" in that they take into account the degree to which transport of ozone and precursors from upwind metropolitan'areas contributes to ozone concentrations at the monitoring site in question.

This smdy described a computer model, Transported Ozone Design Value (TODV), which has been developed to assist in determining the likely source regions associated with high ozone concentration events (Sabo and Hawes, 1990). TODV can only provide an approximate location of the emissions source region likely to have influenced a particular afternoon ozone peak. No estimate of the relative contributions of upwind vs. local emissions to the peak is provided, and back-trajectory calculations based on routine wind data can contain large uncertainties. Selection of the transport-adjusted design value requires an experienced analyst to interpret the results, which introduces a subjective element to the adjustment process. Application of this approach to 1988-90 ozone data yielded transport-adjusted "control strategy" design values for 35 areas. These transport adjustments ranged from a decrease of 0.05 ppm to increases of 0.04 ppm. Thus, these transport adjustments can lead to both decreases and increases in an area's design value as the downwind impact is attributed back to the source area, or the impact from upwind areas is subtracted out.

Adjusting for Meteorological Variability

Meteorological conditions have been shown to play a key role in explaining variations in daily maximum ozone concentrations. Given similar precursor emissions, the basic differences between days when ozone concentrations are average or below average and days when concentrations are high (i.e., episode days) are in the prevailing meteorological conditions. High ozone concentrations are likely to occur with low wind speeds, elevated temperatures, intense solar radiation (i.e., no cloud cover), shallow mixing depths, and the wind patterns that bring, keep, or return high background concentrations to the region. In some years, such meteorological conditions occur more frequently and with greater intensity than in others, leading to a greater number of high ozone days even if precursor emission levels do not differ significantly from those in other years. Thus, design values determined from a single year of data vary in accordance with weather conditions during the year in question and may or may not be representative of design values that can be expected to occur in the future, even in the absence of any precursor emission trends. To some extent, basing design values on three years of data instead of one eliminates some of the meteorological variability, but a single unusual year such as 1988 can still strongly affect the three-year value. This has raised concern that meteorological variability must be considered when assessing ozone air quality trends and judging progress toward attainment of the ambient standards (NRC, 1991).

The influence of meteorological conditions, particularly temperature, on ozone concentrations has been well established (NRC, 1991; Sweitzer and Kolaz, 1984; Jones, 1985; Jones, 1989; Kolaz and Swinford, 1990; Wakim, 1990; Zeldin and Meisel, 1978; Cox and Chu, 1992). The most successful empirical models used in ozone trends adjustments account for roughly 60-80 percent of the variance in daily maximum ozone concentrations (see for example Kolaz and Swinford, 1990; Wakim, 1990; Cox and Chu, 1992). Due to correlations of temperature with other variables, the daily maximum temperature is often the single most important variable in explaining day-today ozone variations. However, since high temperature by itself is not sufficient to produce high ozone concentrations, including other meteorological variables in the analysis often produces better results. This is particularly true at locations where ozone and precursor materials transported from upwind source regions account for a significant concentration increment an high ozone days. High concentrations at such locations are primarily associated with weather conditions conducive to both ozone formation and transport from the upwind source regions.

Much of the year-to-year variability in ozone design values and other summary statistics is attributable to interannual variations in prevailing weather conditions during the high ozone season. These fluctuations can mask underlying ozone trends associated with changes in precursor emission patterns and can affect estimates of design values. As a result, a great deal of attention has been given to the development of procedures for adjusting summary statistics to remove the effects of meteorological fluctuations (Sweitzer and Kolaz, 1984; Jones, 1989; Jones, 1992; Kolaz and Swinford, 1990; Wakim, 1990; Zeldin and Meisel, 1978; Cox and Chu, 1992). A wide variety of methods have been used, all of which rely on the development of a mathematical relationship between ozone concentrations and meteorological factors. This relationship is then used to estimate (predict) ozone concentrations expected to occur under standardized meteorological conditions. Figure l-2 illustrates actual and adjusted trends in the number of days the ozone NAAQS was exceeded in Chicago (Kolaz and Swinford,1990). The "adjusted" summary statistics calculated from these predicted concentrations can then be examined for trends. Figure l-3 shows how an index of ozone conducive days (days with maximum daily temperature greater than 90° F) can be used to adjust the trend in the number of exceedances of the ozone NAAQS (Jones, 1992). Although these approaches are very useful for assessing trends, one must consider how meteorological adjustment affects the intended level of protection for the standard if such an approach were to be used for assessing compliance with the ozone NAAQS.

It may be possible to improve the performance of meteorological adjustment techniques by focusing on meteorological variables that describe the persistence of ozone-conducive conditions over multi-day periods (Cox and Chu, 1992). The importance of persistence and the day-to-day carryover of pollutants has been demonstrated by Kolaz and Swinford among others (Kolaz and Swinford, 1990). EPA has initiated a program to investigate techniques for adjusting ozone trends for meteorological influences. One of the methods being studied is a statistical model developed by Cox and Chu in which the frequency distribution of ozone concentrations is described as a function of meteorological parameters (Cox and Chu, 1992). The results of application of the model to a number of urban areas are encouraging. Figure 1-4 shows the actual and adjusted trends in the 99th percentile concentrations in Chicago. EPA is seeking to review and expand the technical basis for the methodology under a cooperative agreement with the National Institute of Statistical Sciences (NISS).

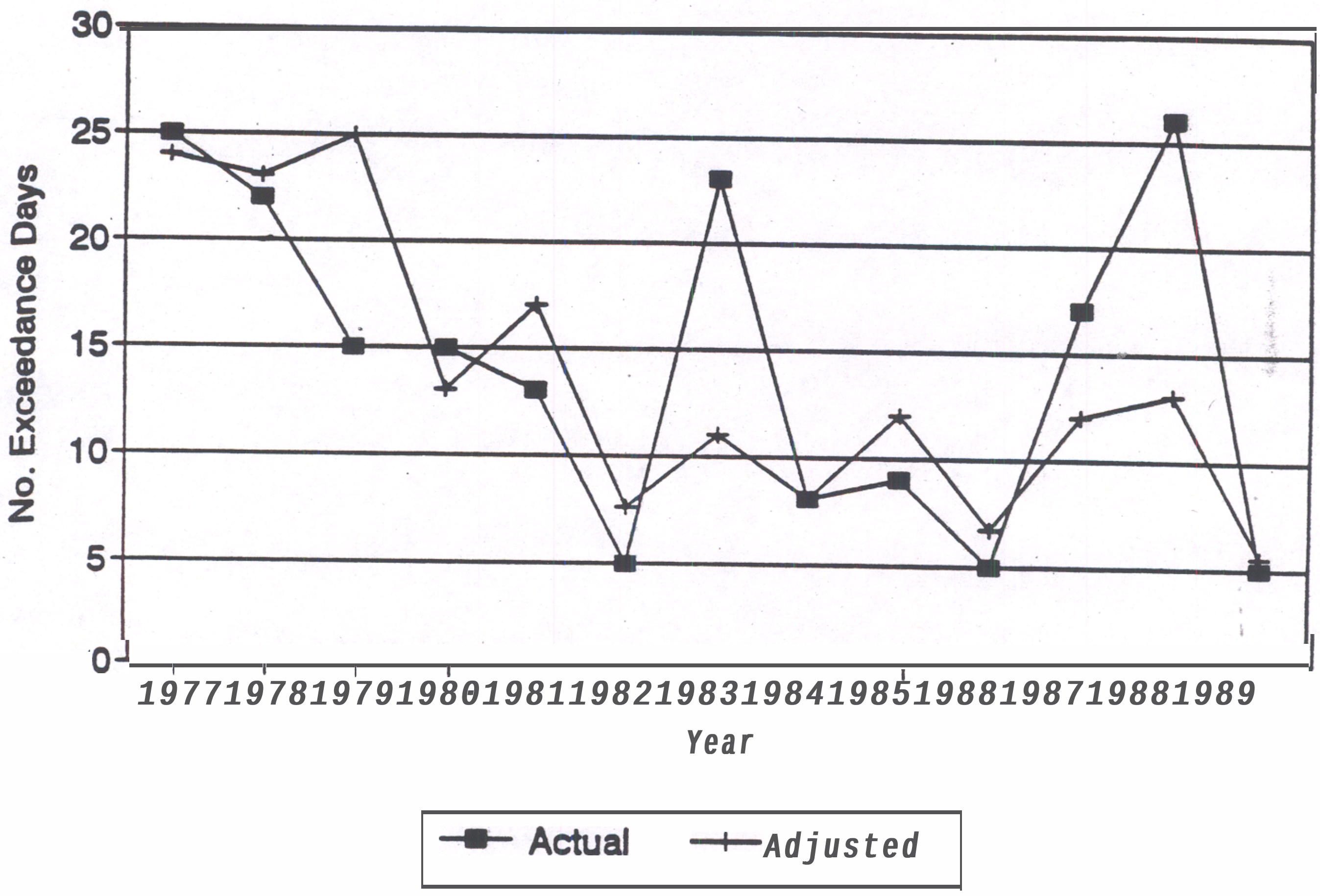

Figure l-2. Actual and adjusted trends in number of days on which ozone concentrations exceed 0.12 ppm in the Chicago area (adapted from Kolaz and Swinford, 1990).

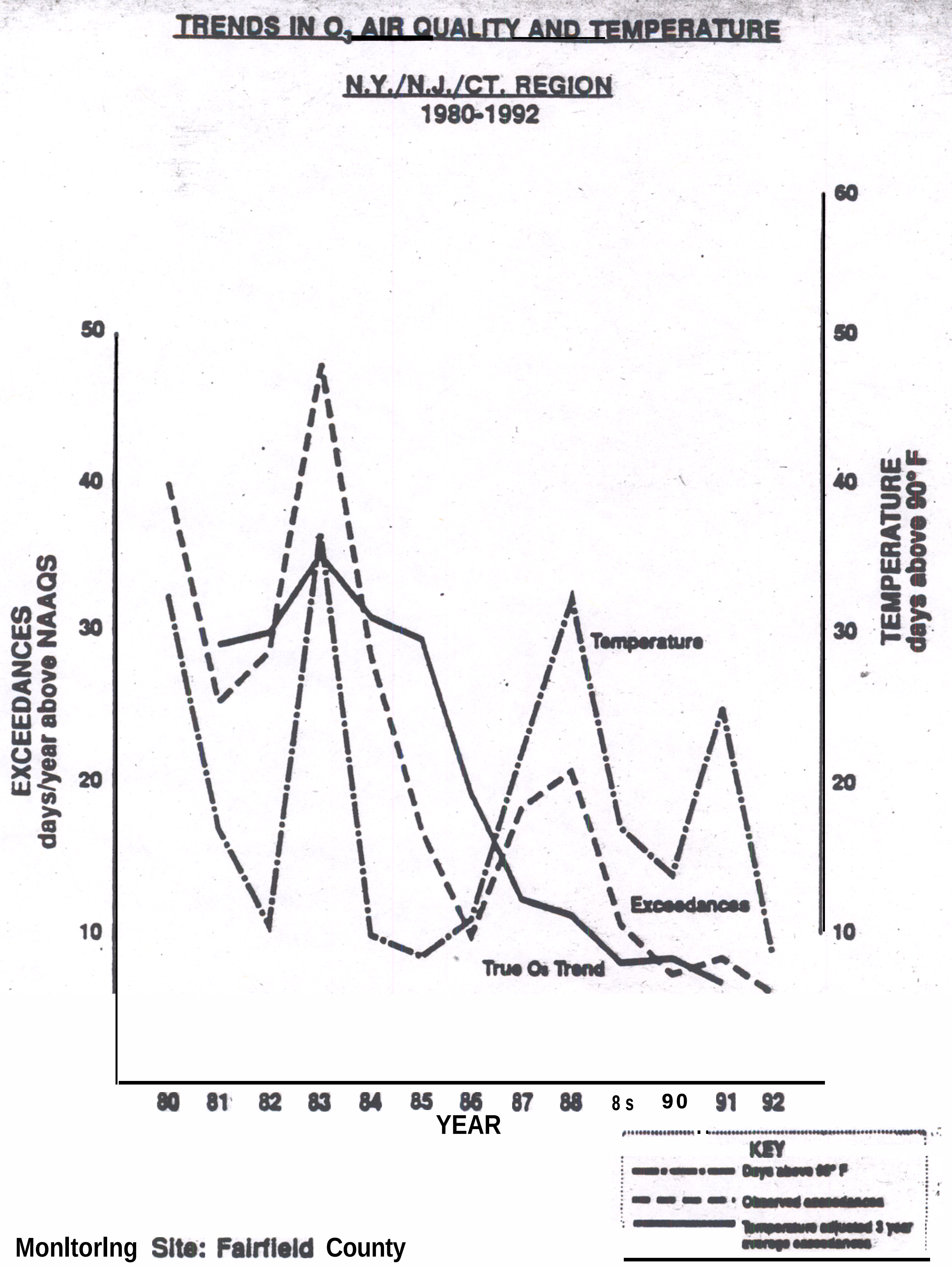

Figure 1-3. Adjustment of ozone trend based on number of days above 90° F (Source: Jones. 1992).

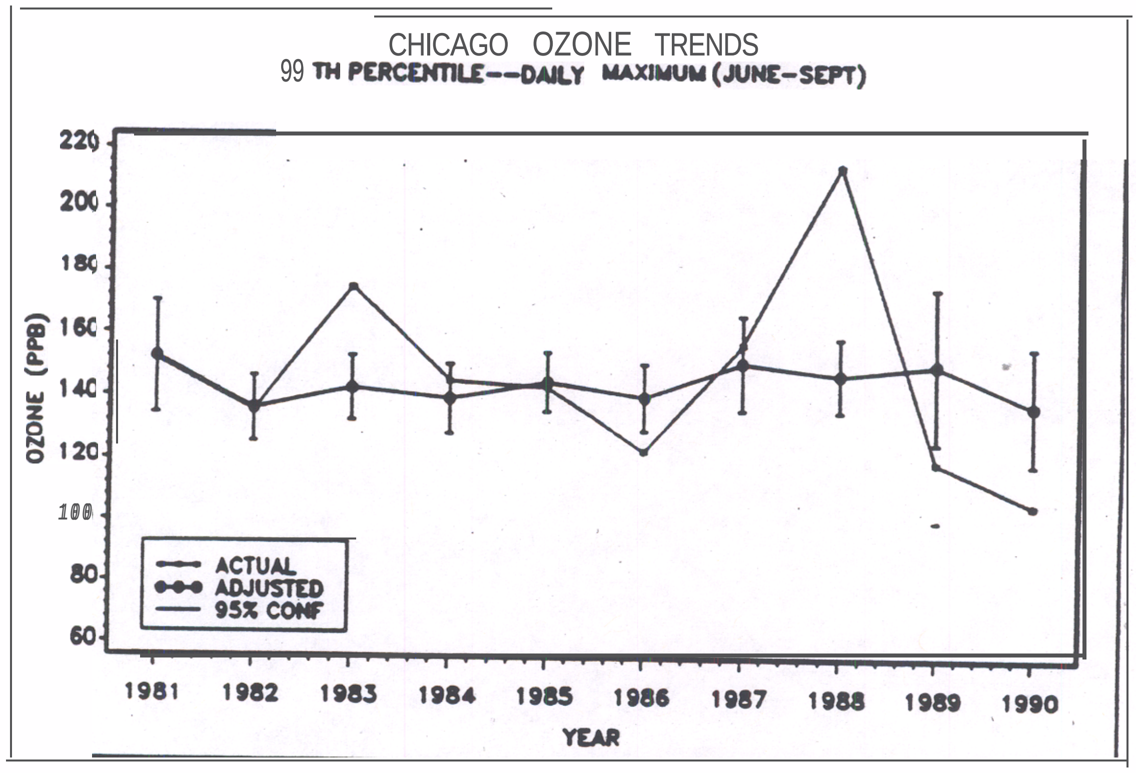

Figure 1-4. Actual and meteorologically adjusted ozone trends in the 99th percentile of the daily maximum l-hour ozone concentration for Chicago, 1981-1990 (adapted from Cox and Chu, 1992).

MAJOR FINDINGS

The Ozone Design Value Study has examined the current EPA method, as well as alternative approaches, for calculating ozone design values. The key findings of the study are as follows:

1. With passage of the Clean Air Act Amendments of 1990, the primary role of the air quality design value is to establish the ozone classification of ozone nonattainment areas.

2. Although the year-to-year differences in maximum ozone concentrations can be large, all of the different methods examined in this study for estimating air quality design values exhibit less year-to-year variability. The EPA design value is slightly more variable than lower percentile indicators and design values estimated from fitted tail exponential distributions, although it remains highly correlated with these indicators.

3. Increasing the number of'years used to estimate the design value reduces the year-to-year fluctuations. Comparisons made for 3-year periods ending in 1988-90 had less variability in the design value estimates than during previous 3-year periods. This is likely due to the fact that there was a single dominant year (1988) for peak ozone levels during the 1988-90 time period.

4. The past decade has seen large year-to-year variability in ozone concentrations, However, the relative variation in ozone concentrations recorded among monitoring sites throughout large urban areas can be as great as, or greater than, the year-to-year variation in ozone concentrations recorded at a particular monitoring location. Spatial variations in ozone concentrations at smaller, sub-metropolitan-length scales are not well defined in many areas due to the sparsity of ozone monitors.

5. The EPA tabular design value method tends to give lower, but more variable estimates for the ozone design value than some of the statistical modeling methods, such as the Breiman tail exponential approach. Results of the time series modeling analysis suggest that the tail exponential approach provides the best compromise regarding bias and precision in the estimate of the "true" design value.

6. Given the database available at the time, generally data through 1989, the use of more robust (less variable) methods such as the tail exponential approach would not have significantly changed the initial ozone nonattainment area designations and classifications. Use of more years of data (i.e., 4 or 5 years) in estimating the design value would have resulted in lower classifications in only a limited number of cases. However, more recent data periods that do not include 1988 yield significantly different results. For the years 1989-91, the first 3-year compliance period that excludes the 1988 data, 42 of the original classified' 98 nonattainment areas have ambient ozone meeting the standard. Seven of these areas have been redesignated to attainment. The most recent compliance period, 1991-93,

has 48 of the remaining 91 classified nonattainment areas also meeting the ozone standard.

7. Since the "true" design value is in the tail of the ozone concentration distribution, the EPA tabular design value method and more robust alternatives are perforce subject to greater variability than estimators of the central part of the distribution. Lie any statistical estimator, errors in these estimated design values can lead to 1990 CAAA misclassification of nonattainment areas, just as errors in the Appendix H estimated expected exceedance rate can lead to misclassification of attainment areas as nonattainment areas and vice versa. Analyses included in this study provide estimates of the theoretical misclassification rates but for a given site and monitoring period it is impossible to determine whether the estimated classification is the (unknown) true classification.

8. The "air quality" design value differs in concept and application from the "control strategy value." The former is based solely on the actual measured ozone air quality data and relates directly to the form of the ozone NAAQS. Control strategy design values have historically been used to evaluate emission control strategies, and may incorporate adjustments for factors such as transported ozone levels and meteorological variability. Use of the control strategy value concept to judge attainment under the Act would require EPA to revise its preliminary interpretation of Section 181(b)(2) published in the General Preamble to Title I.

9. For thirty-five areas modeled, the transport contribution to design values in areas subject to transport was found to be as large as 0.05 ppm. Increases in the design value of up to 0.04 ppm were estimated when the downwind impact was attributed back to the source area.

10. EPA has initiated a program (Cox and Chu, 1991) to investigate techniques for adjusting ozone trends for meteorological influences. One method being studied is a statistical model in which the frequency distribution of ozone concentrations is described as a function of meteorological parameters. EPA is seeking to review and expand the technical basis for the methodology under a cooperative agreement with the National Institute of Statistical Sciences (NISS). Preliminary results suggest that the bias and uncertainty associated with long-trend estimates can be significantly reduced by includii meteorological covariates as parameters in the statistical modeling process.

11. The use of a simple linear function of the 95th percentile of the distribution of daily maximum ozone concentrations as a surrogate design value is less satisfactory than any of the four more diit estimators of the design value. It fails to significantly reduce the variability of the associated estimated characteristic largest value (CLV) below that achieved with the more direct methods. (From another perspective: controlling the 95th percentile fails to improve control of the underlying CLV.) At the same time it introduces substantial biases which vary with the site. The bias problem would result in uneven treatment of sites relative to what would be achieved with the more direct measures. Nor would the use of the 95th percentile obviate the need to use 3-year data sets.

CONCLUSIONS

The question for the Ozone Design Value Study is "Does the EPA design value methodology provide a 'reasonable indicator of ozone air quality in ozone nonattainment areas'?" The answer depends on the intended application of the design value. Each nonattaimnent area was classified as a Marginal Area, a Moderate Area, a Serious Area, a Severe Area, or an Extreme Area based on the design value for the area. The area's classification establishes the primary standard attainment date and the requirements for State Implementation Plans.

In responding to Section 183(g), EPA sought to focus tbis study on whether the design value serves as a reasonable indicator of attainment status as defined by the current NAAQS, progress in reaching attainment, and of how much concentrations must be reduced to meet the standard. The EPA design value method yields an estimate for the ozone design value that is consistent with the current ozone NAAQS. Given the findings of this study, the EPA design value yields a "reasonable" estimate of the "true" air quality design value for the area and of peak ozone levels within the nonattainment area for the initial three year compliance period.

The EPA design value provides a reasonable estimate of peak levels within the urban area, and the degree of nonattainment of the area. However, the design value cannot describe the spatial variability in ozone concentrations across the area. More robust indicators based on specific monitoring sites also have large spatial variability. Ozone design values calculated with the EPA design value method are highly correlated with other more robust indicators. However, due to the spatial variability observed across urban areas, one cannot expect a single numerical value to adequately describe complex concentration gradients across large metropolitan areas.

The current EPA design value method may not provide a reasonable indicator of ozone levels in future years due to the large year-to-year variability in meteorological conditions, or to reductions in emissions following implementation of control measures. However, other more robust air quality indicators also exhibit similar year-to-year variability.

The method used to adjust for meteorological influences on long-term ozone trends could be adapted for use in calculating meteorologically adjusted exceedance rates and design values. While such adaptations are technically feasible, and would reduce the year-to-year variability, the use of adjusted exceedance rates in NAAQS attainment and adjusted design values for classifmation purposes would represent a major departure from current EPA policy and NAAQS implementation guidelines. Also, a meteorologically adjusted design value may not be the best indicator of the air that people breathed during a specific calendar year.

Concerns about the current ozone standard were raised during the public review process. Although changes to the form of the ozone standard were outside the scope of this study, they are being considered within the context of the current review of the ozone NAAQS. The knowledge gamed from me input of all parties to this study during the public review process will be used to address issues concerning the form of the ozone standard and design value methodologies.

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